Soc. Sci. **2015**, *4*, 469–498; doi:10.3390/socsci4030469

OPEN ACCESS

social sciences

ISSN 2076-0760

www.mdpi.com/journal/socsci

Article

Collaborative Resilience to Episodic Shocks and Surprises: A Very Long-Term Case Study of Zanjera Irrigation in the Philippines 1979–2010

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Academic Editor: Oliver Ibert

Received: 1 November 2014 / Accepted: 2 July 2015 / Published: 7 July 2015

Abstract: This thirty-year case study uses surveys, semi-structured interviews, and content analysis to examine the adaptive capacity of Zanjera San Marcelino, an indigenous irrigation management system in the northern Philippines. This common pool resource (CPR) system exists within a turbulent social-ecological system (SES) characterized by episodic shocks such as large typhoons as well as novel surprises, such as national political regime change and the construction of large dams. The Zanjera nimbly responded to these challenges, although sometimes in ways that left its structure and function substantially altered. While a partial integration with the Philippine National Irrigation Agency was critical to the Zanjera's success, this relationship required on-going improvisation and renegotiation. Over time, the Zanjera showed an increasing capacity to learn and adapt. A core contribution of this analysis is the integration of a CPR study within an SES framework to examine resilience, made possible the occurrence of a wide range of challenges to the Zanjera's function and survival over the long period of study. Long-term analyses like this one, however rare, are particularly useful for understanding the adaptive and transformative dimensions of resilience.

Keywords: Philippines; resilience; irrigation; collective; common pool resources; collaborative; social-ecological systems; surprise; shock

1. Introduction

This paper chronicles the resilience of an indigenous irrigation collective, Zanjera San Marcelino, by finding complementarity between theories of common pool resources (CPR) and social-ecological systems (SES). Zanjeras are communal, indigenous, self-governing irrigation systems in the Ilocos Norte region of the northern Philippines. Ostrom ([1], p. 90) draws attention to the long-term sustainability of zanjeras and their success in solving common-pool resource problems. She includes zanjeras among CPR institutions whose success and durability is tied to possessing clearly defined boundaries, congruence between appropriation rules and local conditions, collective-choice agreements, monitoring, graduated sanctions and conflict-resolution mechanisms. What is less well understood is how CPRs like zanjeras respond and adapt to changing institutional, ecological, and cultural conditions over time that demand more than an ability to recover from episodic shocks to avoid undesirable thresholds of change. Are participatory governance and a longstanding ability to respond to episodic shocks also associated with the capacity to generate novel alternatives and mobilize the resources required to adapt to surprises, shocks that are unprecedented and unanticipated?

This case study engages this challenge of considering how community-based resource management can both persist and change over time. It follows the path that Ostrom [1] chose to engage the resilience literature to account for surprises that play out over multiple temporal, spatial and institutional scales. A contribution of this paper that supports this integration of a CPR within an SES perspective is the opportunity it provides to examine institutional resilience over 30 years, with observations drawn from episodes that challenged the viability of the Zanjera San Marcelino. Longitudinal analysis over this time scale is exceedingly rare, and is critical for understanding how institutions persist and adapt in response to episodic as well as novel disturbance.

After an overview of our research methods, we provide a general history of zanjeras and describe how Zanjera San Marcelino deftly deployed longstanding rules and procedures to bounce back from episodic shocks throughout the 1970s, including typhoons, drought, and economic downturns. We then focus on how the Zanjera responded to a new national irrigation project in the 1980s that threatened to supersede the Zanjera's ability to maintain its irrigation system. We consider how the Zanjera and the National Irrigation Administration of the Philippines (NIA) instead learned to accommodate one another during this time. We then address how the Zanjera adapted to surprises that threatened this accommodation during the 1990s and 2000s by reducing their integration with the NIA, and consider how the Zanjera is struggling in the 2010s to address a surprise that threatens its adaptive capacity.

In the discussion, we connect the case narrative to the resilience literature on surprise and adaptive capacity to explore how collaborative community governance was critical to the Zanjera's ability to persist as well as reflect, negotiate, and reconfigure. Contesting the idea that polycentric governance is in tension with strong community-based management [2], we conclude by considering how learning networks can enhance both internal and external connectivity. We suggest that learning networks can increase the autonomy and integrity of community-based collaborative governance by expanding the diversity of options, ideas, and practices that support innovation while enabling community coalitions to better navigate the tides of resilience across scale within a polycentric governance regime. Considered over thirty years, the continued existence of the Zanjera San Marcelino speaks for the continued utility of community-based resource management despite increasing system interconnectedness and dynamism, provided that communities are embedded within a supportive institutional milieu.

2. Literature Review

Ostrom [1] and colleagues describe how CPRs such as zanjeras provide resource users with the ability to govern their own exploitation of a relatively discrete natural resource pool in a sound and enduring way, despite individual incentives to free-ride. Their core insight was that sustainable resource use did not have to rely on private ownership or state control, as long as communities could devise and enforce collective rules and procedures about boundaries, authority, resource allocation, monitoring and sanctioning. Effective CPR communities were able to both conduct routine tasks like allocating limited natural resources and also address special circumstances, including recovery from episodic disturbances such as typhoons. A functioning CPR could normalize shocks by applying rules about how members should cooperate during recovery, such as Zanjera San Marcelino's requirement that members share the burden of reduced capacity after a typhoon washed away irrigation structures while proportionately contributing labor and resources to rebuilding.

Communities were the central locus of these CPR analyses, with other levels of government either left out altogether or described as sources of instability, through application of laws and regulations that conflicted with community procedures and rules [3]. However, over time, analysts began to incorporate a more nuanced appreciation for how higher-level governance could complement and enhance CPRs—and conversely, that appropriation rules and other features of a CPR are fragile when they are not recognized and integrated with external authority [4]. Carrying forward this line of thinking, the scope of CPR analysis was extended to encompass multiple sites and sources of governance and account for cross-scalar influences, including new technologies, demographic shifts, and global markets as well as natural hazards and ecological variability [5,6].

In her later work, Ostrom carried forward this line of thinking by urging institutional analysts to move beyond management "panaceas" that result from mechanical application of CPR principles and recognize that CPRs were a part of complex and dynamic social-ecological systems (SESs) [1,7,8]. A SES framework has far-reaching implications for understanding CPRs not only because it encompasses additional social and ecological processes and actors, but also because it challenges core assumptions of stability and continuity inherent in earlier CPR work. SESs can occupy many alternative system states rather than a single stable state—they may be complex, discontinuous, nonlinear, and unpredictable, integrating human and natural phenomena across multiple spatial scales and timeframes.

In SES thinking, the process of navigating between these shifting possibilities is captured by the idea of resilience. Rather than striving for the efficiency of a single optimal set of conditions or buffering to withstand shocks and maintain function, resiliency is about maintaining structural and functional complexity through periods of disturbance and reorganization [9]. Resilience includes both the possibility of doing the same thing faster and better and recovering to a preferred state as well as exploring and enabling new possibilities, reconfiguring seemingly stable natural and social conditions, and transforming into something new, with profoundly different characteristics [9,10]. As this implies, a system that changes is not necessarily a failure in resilience terms, but could be a result of an intentional effort to express a desirable alternative regime, or a reconfiguration to help avoid a broader system collapse.

This focus on resilience is accompanied by an appreciation for the different ways we can think about disturbance events. Schoon and Cox [11] created a typology of disturbance types that includes flows in and out of a system, parameter fluctuations, changes in network structure, and changes in connectivity between the SES and external nodes or actors. A complementary way to look at disturbance is by considering how stress and shock act at different temporal and spatial, and organizational scales. Smith and Stirling [12] contrast drought as a shock with climate change as a stress, and note that while developing drought-tolerant maize varieties may be a good way to maintain food production in response to drought, consolidating the commitment to a maize-based agronomy can inhibit prospects for a more fundamental socio-technical transition in response to climate change. Walker *et al.* [13] provide a theoretical explanation of this relationship between shock and stress, describing how stress caused by changes in the slow or controlling variables of a system can promote more fluctuation in faster-moving variables in response to shock, which can drive a system across a threshold to another stability regime. Stress or shock can be either episodic or unique, although the episodic nature of longer-term stresses such as climate change can be beyond the capacity of local recollection and institutional adaptation.

This latter issue raises another core attribute of disturbance, which is how it fits into people's experience and how they react to it. We define surprise as an unremembered and unanticipated disturbance of any kind, whether stress or shock, or impact on flows, parameters, or network structure. Surprises matter, because they may cause a significant number of actors in a governance arrangement to question institutional rules and change attitudes and behaviors [14]. Their reaction can initiate social cascades or tipping points, as other people that these actors hold in regard are simultaneously questioning and changing their attitudes and behavior [15,16]. However, when disturbances are anticipated and remembered, they often become normalized through pre-existing agreements on how to collectively apportion labor and resources. Prior surprises may foster responses that may later prove useful, provided that there is a way to preserve organizational memory and response capacity [17,18]. No longer surprises, these disturbances are anticipated and incorporated into cultural patterns, in the way that Sahelian nomads respond to episodic droughts by taking alternative migration routes and relying on cooperative interethnic ties with farmers in permanent settlements [19].

An SES perspective builds on this understanding of how CPRs resist deformation and rapidly recover from episodic or precedential shocks and stress. An SES view considers how surprises can catalyze beneficial adaptive or even transformative change, especially in the presence of governance structures that provide the capacity to address the unexpected, deliberate about alternatives, and manage the transition [20,21]. This additional element of surprise is more attuned to the adaptive possibilities of an SES, beyond the dichotomy of recovery or collapse. This expands our perspective on resilient CPRs beyond optimizing collective solutions to free rider problems to consider how CPRs organize directed and purposeful responses to social and ecological surprises. In this article, we explore how, in addition to achieving resilience through routinized response to a typhoon or other episodic shocks, a resilient CPR can respond to surprise by navigating flexibly and purposively within a complex and dynamic system, adapting in ways that steer away from undesirable trajectories. This may involve enhancing a preferred system identity and function by maintaining some, but not necessarily all, aspects of an existing system [22].

The core questions that motivate this paper spring from our curiosity about the creativity and flexibility of CPRs within SESs. How does a CPR respond to surprises and navigate between alternative systems configurations? Over longer timeframes, do we observe adaptive, deliberative potential in a CPR, as members confront novel and unforeseen system conditions that offer the multiple possibilities of persistence and adaptation? In our discussion we will consider the implications for thinking about a CPR as a governance framework for creative reinvention in addition to its well-established ability to maintain effective rules, procedures, and enforcement mechanisms.

3. Methods and Research History

This research about Zanjera San Marcelino extends over a thirty-year period, drawn from five periods of research by Coward [23], Yabes, and Goldstein (1985–1986, 2006, 2009–2010 and 2012–2015). It began with Coward's [23] detailed analysis of the social organization of Zanjera San Marcelino in the late 1970s, which was based upon field observations and informant interviews. The second period was a 1985–1986 study by Yabes [24] that examined a national irrigation project, the Ilocos Norte Irrigation Project (INIP), which included a number of zanjeras within project boundaries. Two questions guided this research: (1) What was the impact of a large irrigation project that switched from engineering-based to participatory planning upon an indigenous irrigation system that operated as a participatory CPR? (2) How did the zanjeras' CPR regimes change when they began participating in a national irrigation project? These questions were applied to 40 zanjeras, selected through a random stratified sample based on the variables of physical size and location with respect to NIA (National Irrigation Administration) dams. Semi-structured interviews were held with INIP and NIA employees and zanjera leaders, and a survey of farmers was conducted, both of which served as source material for this article. Other information used here was gathered during visits to NIA's Central Office in Manila and a one-week visit to the Japan International Cooperation Agency (JICA), the Organization of Economic and Commercial Fund, and Sanyu, Inc., offices in Tokyo, Japan. Representatives from several Filipino universities also were interviewed. The data collected from these semi-structured interviews included the history of the physical system, history of the social and organizational structure of the system, current and past operation and maintenance (O&M) activities before NIA's involvement, current physical and social structures in place for the zanjera after NIA came into the area with INIP, financial management, NIA system turnover to the zanjera, and the relationship and interaction between the zanjera with NIA throughout the planning and implementation activities of INIP. This article also draws on the more detailed analysis of Zanjera San Marcelino contained within these two initial periods of research, including semi-structured interviews with its officers and members, farmer observation, and participant observation of zanjera meetings. Organizing structure, rules of operation and guidelines for the selection of zanjera officers in the zanjera before and after INIP began were collected and analyzed, and appear in this paper. Data were primarily qualitative and were coded and analyzed through directed content analysis, which uses existing theory as the basis for coding ([25], p. 1283). Coded data were analyzed through frequency analysis, cross-tabulations, and Chi-Square analysis. Some questions that are included in this paper were quantitatively coded such as geographic location, physical size of the zanjera, and area (ha) of irrigated land before and after INIP was introduced.

The third research period took place throughout the 1990s and 2000s, through short visits and correspondence. Yabes visited the Zanjera for two weeks in June 2006 to update Coward's and her own research about Zanjera San Marcelino. Data included in this paper were collected primarily through semi-structured interviews of Zanjera San Marcelino's officers and NIA staff, participant observation of the Zanjera's meetings and activities, and interviews and collection of NIA maps and other documents. Yabes adapted Ostrom's Institutional Analysis and Development coding forms, gathering information about location, organizational structure and process, operational level, and appropriation rules. Research and data collection activities by Yabes and four research assistants included survey questionnaires; semi-structured, short and long interviews of zanjera leaders and members; making or copying zanjera maps that showed the sharing of land agreements and member shares of water; attendance at zanjera meetings, activities and celebrations; data from the National Irrigation Administration (NIA), INIP and the NIA provincial office; data from Municipal Agriculture and Extension Offices; data from the Mayors' Offices in Banna, Dingras, Marcos, Nueva Era, and Solsona; river maps from the Provincial Forestry Office; and maps and information from the Department of Public Works on road networks in eastern Ilocos Norte. Data were analyzed with descriptive statistics and the production of a map (simplified for use in this paper) that included the locations and names of rivers, roads, municipalities, the main and lateral canals of Zanjera San Marcelino, updated laws and regulations, and secondary data. Content analysis was used for data collected through the semi-structured interviews and the notes from zanjera and NIA activities. Updating some of Coward's analysis as well as her own from 1985–1986, Yabes presented a thirty-year retrospective view of Zanjera San Marcelino as part of a panel of the International Association for the Study of the Commons in Indonesia.

During the fourth time period, 2009–2010, Yabes used similar ethnographic methods to collect more information from Zanjera San Marcelino as well as the 40 zanjeras within the Ilocos National Irrigation System (INIS II) boundaries that were studied during 1985–1986. This information informs discussion of changes in irrigation law and regulation in this paper, and was used in some of the maps of ZSM and its geographic context.

During the fifth period of research from 2012–2015, Yabes and Goldstein drew together select elements of Yabes fieldwork to focus on how Zanjera San Marcelino persisted through episodic shocks and adapted to surprises. The two authors regularly exchanged drafts and ideas, with Yabes selecting and structuring the case data and Goldstein developing a unifying theoretical framework grounded in the resilience literature, interpreting the case data within that framework, and drawing conclusions from this analysis.

4. Introduction to Zanjera Irrigation

The earliest written records of zanjeras were by Spanish priests in 1630 [26]. *Zanja* is the Spanish name for ditch, and a zanjera is a communal organization for ditch irrigation. The purpose of a zanjera is to secure a stable water supply and increase access to arable land, which is scarce in the Philippine province of Ilocos Norte [26,27]. Zanjeras governed and managed water as a common-pool resource, with zanjera members expected to participate in water allocation and distribution, maintenance of control structures, and internal deliberation and conflict management and external engagement [28]. Estimates of how many zanjeras existed vary widely because of different definitions of what organizational levels and physical boundaries constitute a zanjera. In 1978, the provincial office of NIA estimated 1000 to 1200 zanjeras were located in the eastern part of the province of Ilocos Norte.

Wet season in Ilocos Norte is from mid-May to mid-October, while dry season is mid-October through mid-May. The main crop grown in the area is rice. Schedules and cropping patterns vary depending on a farmer's choice of rice varieties, types of secondary and tertiary crops and agreements by farmers on cropping patterns in sub-sections within Zanjera San Marcelino. While rice is planted as early as April if early rains come, planting is usually around May. In late season rice is planted as a second crop with a few farmers planting watermelon or corn from mid-September through early January. The third crop from early January to April is usually corn, and often includes vegetables, tobacco or more rice. All of these crops during all seasons require irrigation.

In the 1970s, zanjeras had a shared agricultural land area, a common water source, and brush dams and structures to control irrigation [23]. Coward outlined the three key tasks required to sustain an irrigation system: organization of water allocation, physical maintenance, and conflict management. Coward discussed five principles of organization employed to operate and maintain the zanjera system: (1) proportional rights and responsibilities; (2) multi-level organization; (3) combinatorial organization where "work groups were aggregated and disaggregated in various patterned combinations to fit different maintenance and operation tasks" ([23], p. 32); (4) reserve organizational capability; and (5) cross-cutting group membership ([23], pp. 29–33).

Member participation in zanjera activities is organized around the atar or membership share [23]. The number of and size of atars is fixed at the time a zanjera is formed and does not change unless a zanjera physically expands. Some zanjera members earned usufruct rights to the land by helping to develop and maintain the irrigation system for former hacienda landowners. These members did not own the land that they cultivated, but they had atar because of the "biang ti daga" (sharing of land) agreement ([29], pp. 28–32). The number of atar shares held by each member determined proportionately the division of water and the rights and obligations to the land. Materials contributions and the amount of labor performed were also proportional to the number of atar held. The zanjeras' principle of proportionality fits with Ostrom's design principle of "proportional equivalence between benefits and costs" ([30], pp. 69–70).

4.1. Zanjera San Marcelino

While Zanjera San Marcelino's founding date is unknown and its original articles of incorporation have been lost, a few of the oldest members remember that this document was written in Spanish, and its 2006 president speculated that the Zanjera's Spanish name suggests the origin dates back to the 1800s during the Spanish occupancy. Until the changes in the 1980s, described later in this narrative, occurred, Zanjera San Marcelino diverted water into a main canal from the Madongan River with a diversion dam made of poles, sticks, stones and leaves. Because of the swift flowing Madongan River, Zanjera San Marcelino farmers built teepee-shaped, bamboo structures named "palomar" that were weighed down by heavy stones and connected by a line of large bamboo poles to stand up against the strong current. Water from the main canal flowed for about one kilometer and then was divided into three lateral branches, the main/eastern, middle and western laterals, which each served several sub-sections called gunglos with farm ditches in the service area (Figure 1). All of the laterals, canals and farm ditches were earthen.

The total area of each zanjera in Ilocos Norte varied from as small as three hectares (ha) to large ones with 500 ha or more. Compared to other zanjeras in Ilocos Norte, Zanjera San Marcelino was very large in total area, although, as with the total number of zanjeras in the province, estimates of this size vary. In the late 1970s, NIA estimated Zanjera San Marcelino's size was 1500 ha of rice paddy during the wet season divided into 564 atars or shares [23]. However, in 2010, San Marcelino zanjera officers estimated its total size at 710 ha and the President said it had always been that size. Unlike some zanjeras, such as the Bacarra-Vintar Federation ([29], pp. 67–112), Zanjera San Marcelino did not share any of its water rights [1] or coordinate O&M activities with other zanjeras. While no water is shared between Zanjera San Marcelino with other zanjeras, downstream Zanjera San Rafael accessed spring water as its water source, while Zanjera Casabaan-San Carlos had access to year-round ground water at the surface.

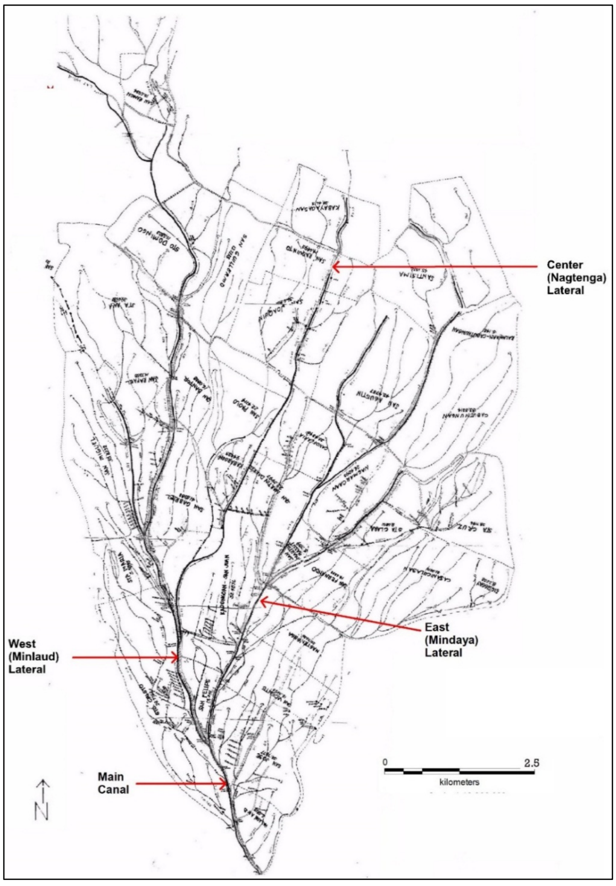

Figure 1. Zanjera San Marcelino map indicating main canal and lateral canals. Source: [32].

[1] Prior to the legalization of water rights, zanjeras had obtained water from their brush dams for their own use. In 1976, "the New Water Code of the Philippines allows only individuals or juridical persons to obtain rights for their use of water" ([29], p. 74). Under the New Water Code, water allocation is determined so that the measure and limit shall be beneficial. The content of water rights are the purpose of use, points of diversion, method of diversion and extraction, maximum amount of water, times during the year when water may be diverted, terms and conditions and annual water charges [31]. Water rights are not expressed in atars.

Zanjera San Marcelino was divided into 32 gunglo sub-sections. Gunglos differed in area and number of atar shares. In San Marcelino, atar size in gunglos ranged from 1.2 ha to 1.6 ha. Some gunglos were as small as 1 ha to 3 ha, while the largest gunglo was 70 ha in total area. Some zanjeras in other parts of Ilocos Norte had total areas that are the same sizes as San Marcelino's gunglos.

Gunglos were divided into two or three zones that were roughly perpendicular to the irrigation canals. Each zone was divided up into an equal number of parcels repeated across each zone [23,29]. Figure 2 is an example of a gunglo that had five members, each with one atar share. One atar share had one parcel of land in each of the zones so that each member had an upstream, midstream and downstream parcel in those gunglos with three zones. As a result, water scarcity was shared by all gunglo and zanjera members and the arrangement inhibits water stealing.

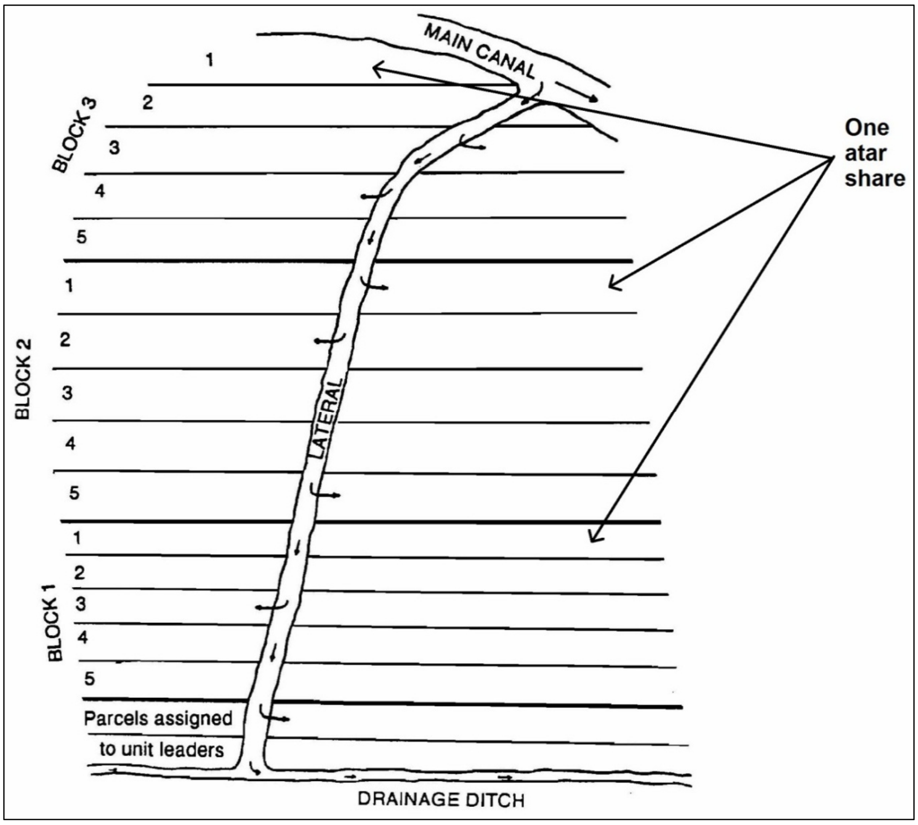

Figure 2. Illustrative layout of fields in a gunglo unit. Source: [23].

Approximately 400 members worked in Zanjera San Marcelino during the 1970s. Three levels of organization of Zanjera San Marcelino (gunglo, lateral and zanjera) reflected the scales of work required by members who engaged in routine and emergency O&M tasks on the dam and canals. Agbuntay labor, the routine work of removing vegetation, gravel or siltation from canals, was performed at the lowest gunglo organizational level. Sarungkar work along the lateral area was routinely scheduled O&M by the zanjera leadership, who assigned labor and material requirements to each gunglo relative to their number of atar shares. If a small amount of labor was needed, one to two days of sarungkar was held, which required each gunglo to send two people for every 10 atar. When major construction or repairs to the main brush dam was required (Figure 3) or the Zanjera needed to clean long sections of the main or lateral canals, the Zanjera leadership would declare a dagup, which required that each atar send a member. Atars holders who did not contribute labor were required to pay a substantial annual fee.

Figure 3. Zanjera San Marcelino farmers re-building bamboo, stone and brush dam (INIP Madongan Dam under construction in background). Source: Photo taken by Ruth Yabes, 1985.

Zanjera San Marcelino maintained specific allocation rules for water sharing within and across gunglos. Schedules for days and times of delivery, labor assignments, water rotation, fines for water stealing and other transgressions aided the equitable distribution of water.

Zanjera San Marcelino was coordinated at three levels (zanjera, lateral and gunglo), with active multi-scale cooperation across the Zanjera. Members were elected from the membership every four years and could be tenants, lessees or owner-operators. A set of officers was in place for each of the three levels of the Zanjera, with the gunglos at the lowest level led by a panglakayen or president, often a secretary and sometimes a vice-panglakayen or vice president. At the middle level, a segundo cabecilla was the leader of the section for one of the three lateral canals in the Zanjera. The mayor cabecilla (president), a secretary, sub-secretary and treasurer led at the top level of the Zanjera. Internal organizational activities included decision-making by majority vote, consensus on major zanjera decisions, or top-down decisions by leaders on minor matters. Zanjera San Marcelino held annual elections for officers at all three levels of organization. In recognition of the time and hard work put into the Zanjera by officers, members paid them an annual honorarium.

In addition to the work rules detailed above, the Zanjera had rules for meeting attendance and materials contributions, conflict mediation procedures to deal with allocation conflicts within and across gunglos, and had the ability to fine offenders through collaborative interaction within and amongst gunglos and the Zanjera. Fines were charged for having a section of a gunglo canal full of dirt, plants and wood, doing laundry or bathing in the farm ditches, or having farm animals in the canals or ditches. Water stealing was the most serious offense and had the largest fine. For water stealing conflicts, the procedure was first to resolve the conflict at the gunglo level, address remaining disputes at the lateral level, and finally refer particularly intractable or serious disputes to the Zanjera San Marcelino president and officers and the gunglo leaders.

4.2. Bouncing Back from Shocks: Zanjera San Marcelino through the 1970s

One of the factors contributing to Zanjera San Marcelino's long durability was its resilience to episodic shocks, especially natural disasters (typhoons), climate stressors (drought), and economic downturns:

Typhoons: Brush dams, padilas (weirs) and ditches and canals were resilient to the flood conditions associated with typhoons. Although the brush dam's bamboo structures and heavy stones were sturdy enough to divert water into the main canal, the materials also had the flexibility to wash out during severe flooding to minimize dumping excess water and gravel siltation onto arable farmlands. This flexibility was also advantageous if the river channel shifted since the brush dams could be re-built in different locations, subject to approval by zanjera members. In years with repeated typhoons, the Zanjera re-built its stick, stone and brush dam as many as five to ten times per year. In each case, Zanjera leaders and members quickly mobilized dagup (all working zanjera members) labor to re-build their dam and clean out gravel and silt from canals in less than ten days (Figure 3).

Drought: The Zanjera was also highly resilient to conditions of limited or erratic water availability during dry season, relying on rules for scheduling water allocation and rotation. The amount of water delivered was determined by the area of the gunglo. The width of a gunglo's irrigation ditch was proportional to the amount of water to be delivered and the area of the gunglo. The larger a gunglo was the wider is the gunglo irrigation ditch. When severe drought occurred, zanjera leaders directed gunglos to reduce proportionally the area to be irrigated. For example, if a gunglo had three zones in its atar system, one response was to cut water off entirely to zone three where all members had a partial atar share, thus sharing water scarcity.

Economic downturns: When harvests were low or incomes were affected by adverse market conditions, the Zanjera would continue to function because it relied on water rotation adjustments and changes in the availability and amount of water allocated amongst the laterals and gunglos to affected laterals and gunglos; member contributions of materials (bamboo, brush, and stones); and working tools and collective labor. In addition, dagup work (all working members with one atar) could be scheduled that could provide some income redistribution within Zanjera San Marcelino, as the landowner's group at that time contributed money to buy food for the workers. The Zanjera also turned to the municipal government for money to repair roads and bridges that provided access to their irrigation system.

4.3. Surprise: The Ilocos Norte Irrigation Project and System

Until the early 1980s, Zanjera San Marcelino was an independent and largely self-sufficient zanjera that managed its own water rights, irrigation system, labor, and O&M. This longstanding independence ended with the introduction of a new and powerful actor, the National Irrigation Administration (NIA), the driver behind the Ilocos Norte Irrigation Project (INIP) and System (INIS II).

NIA is a public corporation created in 1964 as part of the central government's efforts to achieve self-sufficiency in rice production through major irrigation construction programs, emphasizing modern technology and engineering. NIA served three types of irrigation systems: national, communal and private. NIA defined communal systems as smaller irrigation systems that served groups of farmers, although they did not include in this definition traditional, local or indigenous irrigation systems such as zanjeras that operated with little or no input from the government or outside agencies [24,28,33–35]. The O&M of NIA communal systems was the responsibility of irrigator associations (IAs), a legal body made up of the farmers who used the water and were obligated to pay fees as well as repay the cost of the construction ([36], p. 2).

The impetus for NIA's initiative in Ilocos Norte where Zanjera San Marcelino is located was two-fold. First, addressing low agricultural productivity by developing an integrated irrigation system in the area was identified as a priority by NIA's provincial irrigation office. The second motivation for the project was political. President Ferdinand Marcos and his sister, provincial governor Elizabeth Marcos Keon, wanted NIA to dam the Quiaoit River in Ilocos Norte. This was ostensibly for flood control and irrigation, but a NIA staff member suggested that their real motivation was to save the Marcos' family home in Batac from river flooding. After this request was deemed infeasible by NIA, Governor Keon asked NIA in 1977 to study other possible dams that would irrigate lands in Ilocos Norte, including one on the Palsiguan River. Eventually, a feasibility study and pilot project was initiated in partnership with the Japan International Cooperation Agency (JICA) and NIA. JICA and NIA drew up plans for the Ilocos Norte Irrigation Project (INIP) in two phases, which would include a network of irrigation and drainage canals supplied by five new diversion dams (Figures 4 and 5). Due to insufficient national funds, the Palsiguan Dam, Reservoir and all Phase 2 areas were not built.

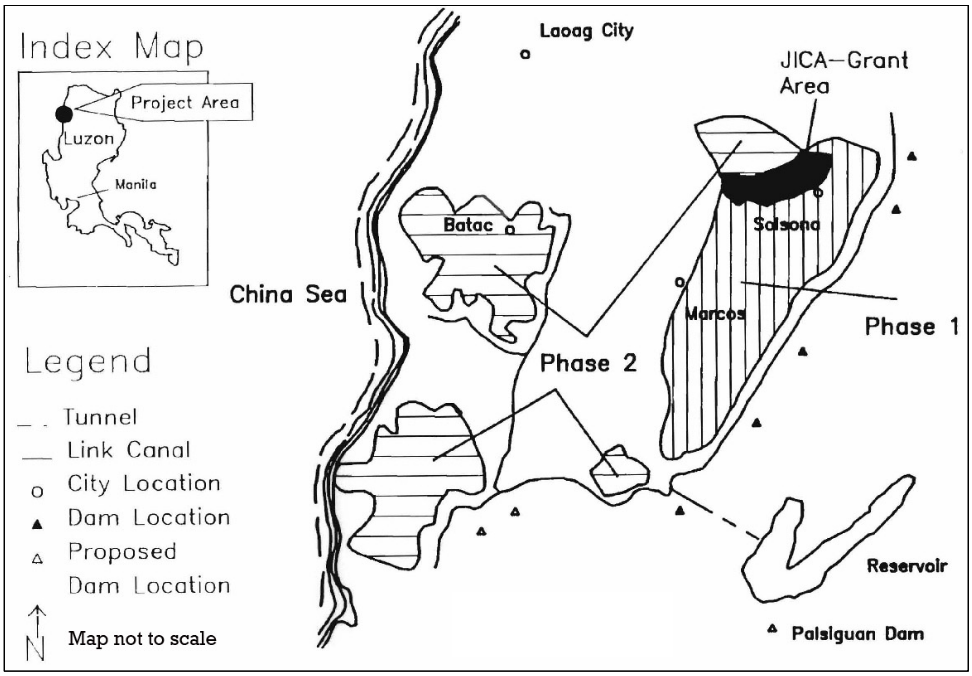

Figure 4. Index map of the Ilocos Norte Irrigation Project (INIP). Source: Map prepared by Ruth Yabes, 1990.

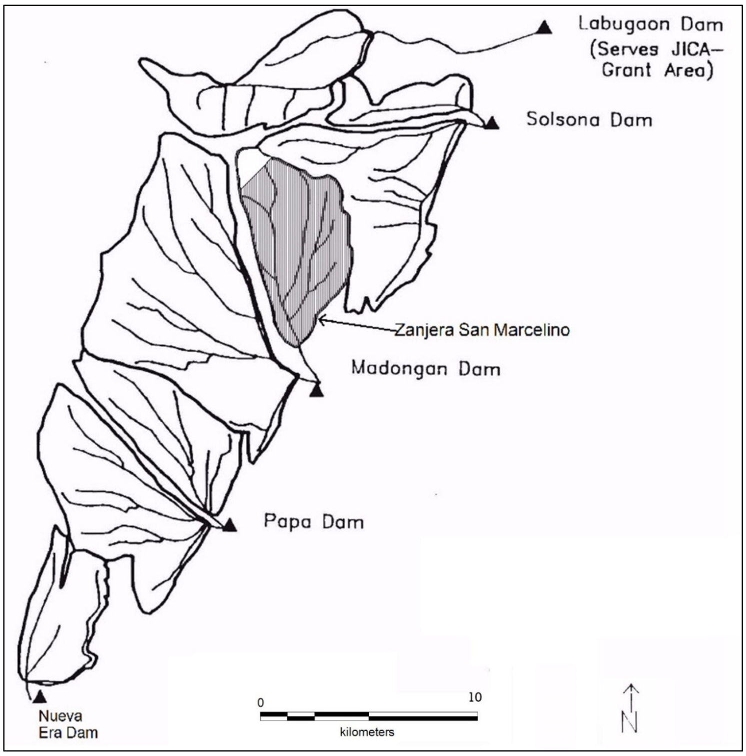

Figure 5. Ilocos Norte Irrigation Project Map. Source: Map prepared by Ruth Yabes, 1990.

JICA funded an initial 1000-hectare pilot project within INIP's service area boundaries. Initially NIA and JICA approached the INIP pilot-project and pre-construction activities as solely an engineering problem of design, construction and water delivery. Once they had identified the most efficient solution they began to implement it by building a dam in the pilot area across the Labugaon River with very little consulting of the approximately eight zanjeras within the service area or taking into account existing zanjera canals.

Many zanjera farmers in the INIP pilot area were angry about how NIA excluded farmers from decision making as well as the impact on their farmland and irrigation canals. During this time, zanjera leaders and membership in the pilot area held many meetings and met informally to discuss the project, and they agreed on a list of concerns: they had enough water without the government's project; they did not want to pay the government irrigation fees; they did not want to cede their long-held, hard-earned water rights over to NIA; they were afraid that the right-of-ways for wider NIA canals might wipe out some of their smaller parcels; and they did not want to give up their zanjeras' physical irrigation systems or collective management structure and be folded into one of NIA's Irrigators Associations (IAs).

Based on these discussions, zanjera leaders advised their membership to not sign right-of-way waivers or pay irrigation fees. NIA engineers responded by offering to take zanjera leaders on field trips to demonstrate the benefits of similar projects elsewhere. Leaders of three zanjeras were not swayed by this offer, and organized bulldozer blockades and other civil disobedience activities that brought the INIP project to a standstill. The zanjera leaders also gathered funds to send a delegation to the national NIA Central Office, where they met with the Chief Administrator to present their concerns.

As a result of this campaign, NIA dropped three upstream zanjeras from the pilot area as the zanjera leaders had requested, and ordered a temporary stoppage of the entire project. In 1985 NIA's Central Office Administrator mandated that the loss of 500 ha upstream be removed from the Pilot area, while adding 500 ha to the western edge of the Pilot area. INIP staff were ordered to start over and completely revise the project planning process [36,37].

4.4. Adaptation: The Zanjera-NIA Hybrid

Fortuitously, at about this time, NIA was developing a more participatory approach to developing communal irrigation systems. NIA management had long been troubled by farmer resistance to projects, as well as the difficulty in collecting irrigation fees from farmers, cost over-runs, irrigated service areas which were smaller than their design targets, and weak irrigation associations [37–39].

In 1976, ten years before, NIA began to consider alternatives to an engineering-centered approach that would enable joint management in partnership with strong local organizations that would enable farmers to plan, design and construct their own irrigation improvements ([40], p. 70; [41], p. 31). This approach was piloted in 1976 in two Central Luzon sites, and then expanded to 203 sites by May 1984 ([38], p. 3). NIA involved farmers in irrigation system management in three stages. In Stage 1, maintenance responsibilities for sections of the major canals were contracted out on a fee basis. During Stage 2, NIA would share O&M responsibilities with a farmer communal association. Stage 3 called for a complete transfer of these responsibilities ([42], pp. 2–3). This revised approach pushed NIA staff to collaborate with zanjera farmers and preserve as much as possible the existing physical canal systems and social organization of the zanjeras.

However, this shift was contingent on the existence of strong local organizations for NIA to partner with. Even with this new policy, NIA continued to have difficulties with operation, maintenance and fees collection because it was difficult to either find effective existing communal farmer associations or establish and maintain new ones. INIP's Project Manager and staff concluded that project success was highly dependent on farmer participation in the project at the planning stages and throughout the construction and turnover process ([43], pp. 15–19).

Informed by this experience, NIA's Central Office Administrator mandated that INIP project office staff completely revise the project's planning process in 1985 [36,37]. INIP's planners did not have much difficulty implementing a more participatory approach because they were operating in area where there were well-established zanjeras who were already convinced that they could be part of a better alternative to NIA's engineered and centralized approach. INIP planners began by designating the existing zanjeras as Irrigator Associations (IAs) in the INIP service area, instead of replacing zanjeras with IAs, which was done throughout the rest of the Philippines. The remaining canals and ditches to be constructed, including those in San Marcelino on the right side of the Madongan River, were jointly planned to some degree by the zanjeras and NIA.

While these arrangements did not necessarily cause NIA engineers to recognize always the benefits of consulting with farmers or alter their engineered systems to incorporate traditional irrigation technologies, the development of formal institutional ties between the Zanjera and NIA led to increasing opportunities and willingness to collaborate ([43], pp. 15–19). For example, in the mid-1980s NIA engineers sought to replace Zanjera San Marcelino's existing flow-dividing padila irrigation structure with concrete and steel double-gated turnouts (Figure 6). The original padila illustrated in Figure 6 shows a farm ditch whose width was proportional to the number of atar in the gunglo, which also proportionally allocated water. The sangi was a concrete protection wall that prevented earth from eroding into the ditch and the lateral canal. The tablon stabilized turbulence in the water. The padila divided the water between the ditch and canal. The farm ditch was left open when it was the gunglo's turn to receive water. When the water rotation went to other gunglos, wood and leaves were stuffed at the point of the padila to block the entrance of water in the farm ditch. Zanjera leaders asked NIA engineers instead to modify and improve the design of the padila rather than build double-gated turnouts [24]. The Zanjera's written request was denied. After zanjera leaders and members reacted swiftly and angrily to this denial, the engineers responded in a familiar way—by organizing a field trip to other irrigation projects so Zanjera San Marcelino farmers could see how successful other double-gated turnouts were.

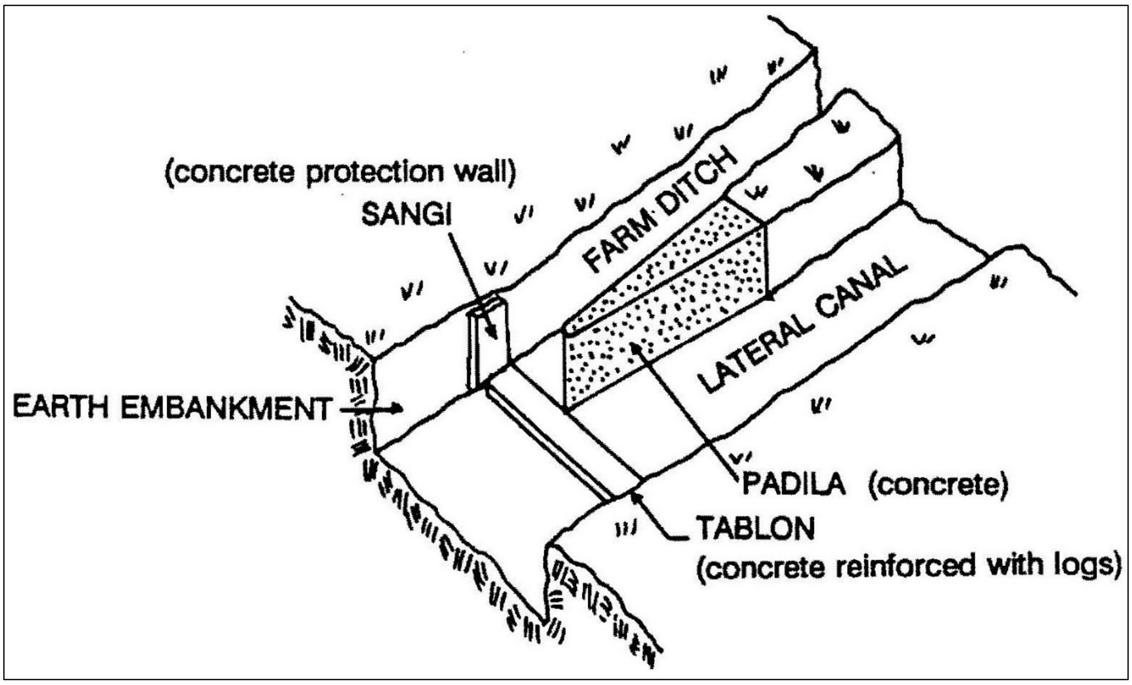

Figure 6. The Existing Padila and Tablon. Source: [44]. Illustration by Patricia Ammerman, 1990.

As before, this only made Zanjera opposition to the double-gated turnouts grow stronger. However, what happened next was different. A number of project engineers were invited to visit the area to see the traditional padilas in action. After these visits, many of the engineers acknowledged that the padilas were indeed better because they were functional, cheaper to construct, and easier to maintain and repair. Soon after, INIP administrators approved the Zanjera's proposal to collaborate in making improvements to the padila design (Figure 7). This shift in perspective and policy traveled up the chain of command to NIA Central Office, which soon after issued a memo discouraging the use of double-gated turnouts nationwide because of the recognition that the traditional structures were a viable alternative to double-gated turnouts, many of which had become inoperable. Zanjera leaders, in turn, recognized that engineering adaptations by NIA would create technical and physical adjustments that would improve the padila's performance in water delivery. NIA engineers provided improvements that included flashboard grooves and steel plate inserts replaced wood boards to block or open gunglo and lateral canals. Steel replaced the original concrete and wood tablon. Concrete walls at the beginning of the gunglo canal replaced earthen ones. NIA's improvements made the padila stronger and more resilient to typhoons.

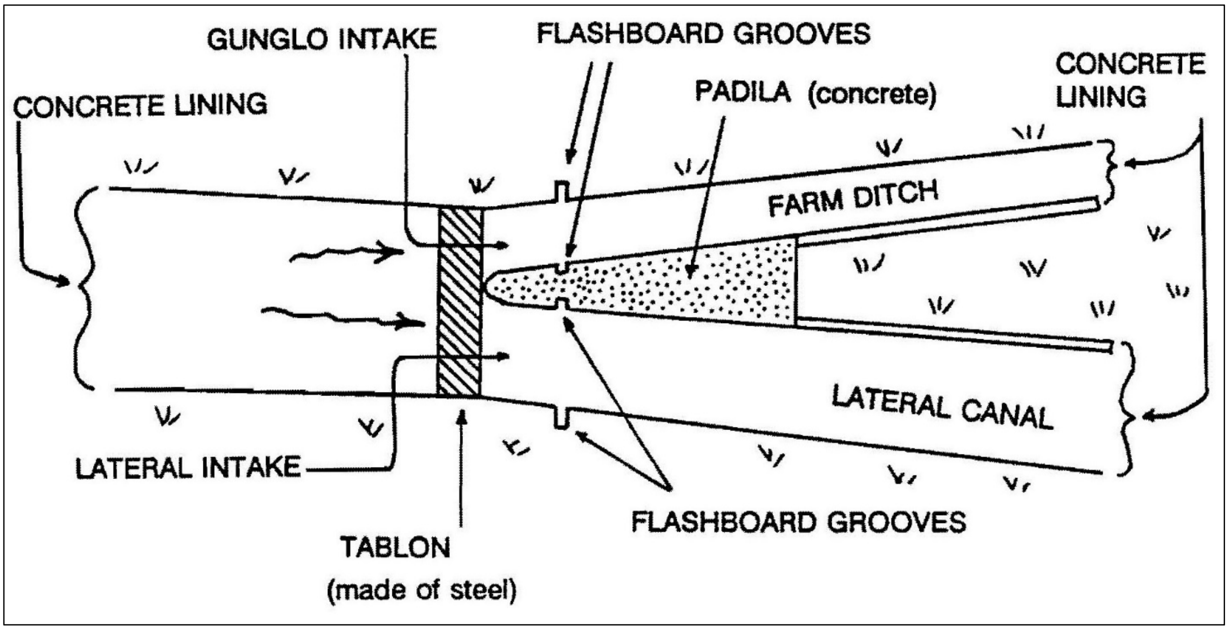

Figure 7. Improvements to the padila and tablon by NIA and Zanjera San Marcelino collaboration. Source: [45]. Illustration by Patricia Ammerman, 1990.

NIA worked with Zanjera San Marcelino to register the Zanjera with NIA and the national Securities and Exchange Commission, and provided training so that the Zanjera could assume management responsibility for the new system. Zanjera leaders quietly commented that they knew much of what was covered in the training regarding irrigation and the only new information was learning NIA terms for structures, financing and taxes.

4.5. Political and Ecological Surprises

The abrupt departure of President Ferdinand Marcos in February 1986 came as an unwelcome surprise to many people living in the province of Ilocos Norte. Marcos had always looked out for his allies in his home province, and had ensured a steady stream of funding for irrigation projects and other infrastructure [46]. This largesse dried up after he left the country, including support for a high reservoir dam that would have dramatically expanded INIP's service area. In total, five NIA dams were built—Labugaon, Solsona, Madongan, Papa and Nueva Era—with a projected service area of 17,000 ha. Unfortunately, NIA did not or was unable to fulfill its commitments to zanjeras in the project area including Zanjera San Marcelino. As of 2008, the total irrigated area shrank from 14,154 ha, to 8021 ha in the INIP area, with approximately 2200 ha in the Madongan Right and Left areas. Due to loss of funds, zanjeras' access to other waters sources, such as springs, or no water delivered, only 40 out of more than the original 100 plus zanjeras signed into INIP. Some additional zanjeras wanted to join the project but NIA had no funds to extend or build new canals in order to provide water to them.

While construction was completed in 1991 it took another five years for the agreement to be finalized between NIA and the zanjeras and turn over of the project into a complete national irrigation system over to the NIA Regional Office [47]. In this 1996 agreement, NIA agreed to manage and operate the five dams and the siphons at the headworks while the zanjeras agreed to operate and maintain the canals and structures. The agreement also addressed how to deal with damages, requiring zanjeras and their members to do any earthwork of less than 100 cubic meters by themselves, while NIA would finance work greater than 100 cubic meters [47].

Since Marcos left, INIP had been slashing staffing levels and support for infrastructure and canal improvements that had not yet started construction. From 1980–1984 funding levels and staff numbers were building up. During 1984–1986 there was strong funding that supported the largest staffing numbers during the project and as an operating irrigation system. Staff type examples ranged from engineers and construction workers to community organizers. From 1997–2010, due to great reductions in national and provincial NIA funding, NIA INIS II had bare bones staff who mostly collected levies from ZSM and other zanjeras and paid the dam gatekeeper.

The impact of these cutbacks became acute after typhoons Feria in 2001 and Igme in 2004. These and other typhoons damaged NIA's Madongan Dam and conduits, and caused gravel and silt to overflow into the canals and farmland. Zanjera San Marcelino's water management system was rendered inoperable, since at this point the dams had become fully integrated into the Zanjera's water management system.

The Zanjera tapped into its existing organizational capacity by mobilizing its integrated, three-tiered labor system to use NIA equipment to perform the critical tasks of cleaning the siphon and repairing the headworks, which was contractually NIA's responsibility alone. However, after these and other typhoons, NIA delayed making necessary repairs due to lack of funding and construction materials, and reduced Zanjera San Marcelino's service area from 710 to 670 ha. A 2010 NIA chart prepared by ZSM leaders shows that ZSM has a total of 741.8697 ha, however, some areas are neither arable nor irrigated. Farmers in gunglos that are not receiving irrigation currently still pay taxes every year in the hope that the lands will be cleared of gravel and irrigated once again. NIA's contribution to the Zanjera-NIA hybrid is to collect fees and pay NIA's gatekeeper to open and close the gates to the right side of Madongan River, looking north. NIA also responded to major typhoons by building redundancy into the system by constructing a second emergency canal intake and an open main canal around 2005.

The Zanjera did the rest. The members and leadership began to assume NIA responsibilities and build complementary infrastructure, including brush dams to divert water NIA's main canal to irrigate the gunglos after the Madongan Dam and headworks were badly damaged and not repaired. In late 2009, the Zanjera built its new form of dam with sandbags on the west side of a small spillway at the second emergency intake to divert more water into the main canal. Sandbags were used as needed at the ratio of two bags per gunglo. The failure to abide by NIA's initial agreement of shared responsibility continued to exacerbate tensions and farmer non-compliance in paying fees. As of 2010, fewer than 30% of farmers paid their annual levies to NIA, which in turn resulted in insufficient resources to repair damaged infrastructure, further discouraging farmers from paying the fee. However, the Zanjera's use of sandbags, O&M of the main and lateral canals, and other infrastructure made up for the loss of irrigation water from NIA.

The Zanjera members' priority was to still pay honorariums to Zanjera and gunglo officials, first, and then paying reduced fees to NIA. In the attempt to collect as much money as possible, however, NIA collects its fees a few days before the Zanjera officers are paid.

Other issues arose during the same time period that may have had a more disruptive impact on Zanjera San Marcelino. In 2010, the president of the Zanjera noted that since the Madongan Dam was completed there was a growing "free rider" problem where some members did not work or pay fines. Possible reasons he provided were an aging membership, economic diversification that diminished their availability, and disruptions related to land inheritance, as well as agrarian reform, which increased the difficulties of coordination after many tenant farmers became landowners. As this suggests, while these threats are driven by seemingly positive developments institutionally far removed from the Zanjera, they could have an impact on the Zanjera that may be more damaging than a typhoon. For example, driven by concerns over gender and sibling equity, changes in Filipino national inheritance law require equitable land division for descendants [48]. If this leads families to split up atar parcels, this can interfere with the way the zone system reinforces common interests. For instance, a father may own one atar share split into three parcels in three zones. When he dies, if he has six children, each is entitled to one half of one of the three parcels in a zone. Family disagreements and failure to make arrangements to avoid splitting the land into tiny sections may result in land fragmentation, undermining the original land patterns of atar shares and the related rights and responsibilities, and altering the three zone atar arrangement, thus breaking the internal physical check that discouraged upstream zone cultivators from stealing water from the lowest zone farmers. Of 36 gunglos in ZSM in an area of 740 ha, nine have intact atars (in hectares), 25 have parcels that are split from a tenth to a thousandth of a hectare. Two other gunglos show one atar in hectares split three ways.

In response to problems like these that many zanjeras were facing, a federated, provincial association of zanjeras in National Systems was created in 2010 in Ilocos Norte province called the National System's Federation-Ilocos Service Associations Group. This association provided support for Zanjera San Marcelino through forums for information sharing and collaborative learning amongst zanjeras, their leaders and members.

This entire historical timeline is summarized in Table 1.

Table 1. Timeline highlighting episodic shocks and surprises to Zanjera San Marcelino (ZSM) and responses.

Dates	Episodic Shocks and Surprises	Responses
Pre-1970s to early 1980s	Typhoons	Bamboo, log and stone diversion dam wash away during flooding, protecting farmland, and all work units mobilized for repairs
	Drought	Rotational irrigation modified during drought
	Economic fluctuations	Flexibility in member contributions and allocations in response to economic conditions.
1983–1985	Construction begins on National Irrigation Agency (NIA) dams that would supersede zanjera system	Some other zanjeras resist and refuse to sign over their water rights and join government irrigation associations.
		NIA adopts more collaborative approach
Mid-1980's	NIA engineers propose turnouts that ignore ZSM's padila technology	Engineer/farmer field visits lead to retention of padilas

Table 1. *Cont.*

Dates	Episodic Shocks and Surprises	Responses
1986–2000	After President Marcos flees country, construction, operation and maintenance funding dry up	Realignment of management responsibility: NIA maintains dams and major infrastructure and ZSM maintains canals.
2001–2004	Typhoons caused damage to the dams, headworks and canals and flood farmland with gravel	ZSM mobilizes its integrated three-tier labor system, borrows NIA equipment, pays for fuel to make repairs, cleans headworks and canals, agrees to maintain headworks and main canal
2010	NIA fails to maintain agreement with ZSM to maintain the dam, headworks and main canal	ZSM farmers pay little or no irrigation fees to NIA
2010 onwards	Many ZSM members do not do their share of work or pay fines	None
2005–2010 onwards	Filipino inheritance laws requires sibling equity in land division	Atar parcels split up into smaller parcels
2009-onwards	Organization of province-wide zanjera learning network	Information sharing and interaction among zanjera leadership

5. Discussion: Episodic Shock, Surprise, and Resilience

5.1. Introduction

Looking over this three decade long Zanjera San Marcelino case study, a broader perspective on institutional persistence and adaptation emerges that has telling implications for our thinking about resilient, community-based resource management. Over this period of observation there were repeated episodic shocks, as well as stress and surprises that were outside of the experience of Zanjera members and leadership. In the following discussion, we will highlight some of these social and ecological disturbances and the different response strategies the Zanjera pursued. After episodic shocks, including droughts and typhoons, Zanjera San Marcelino quickly set into motion established procedures that spread the burden equitably and facilitated rapid recovery of its water delivery system. When potentially devastating surprises occurred, the Zanjera responded nimbly and creatively, deploying a variety of strategies over the spectrum from resistance to accommodation, sometimes forging new collaborative partnerships, and other times withdrawing from these relationships when the partnerships brought on new surprises. We link this ability to both persist and adapt to Zanjera San Marcelino's collaborative governance structure, adopting a social-ecological systems (SES) perspective that integrates concern with the rules and procedures that enable periodic recovery with the capacity to adapt institutions in response to dynamic and uncertain conditions. We end the discussion by describing how seemingly benign recent stresses are threatening to unravel the Zanjera's ability to continue to respond to ongoing shock and surprises.

5.2. CPRs Bounce Back from Shock

At the beginning of this thirty-year study in the late 1970s, Zanjera San Marcelino had the hallmarks of a classic common property resource regime ([23]; [30], pp. 67–79). Members shared an agricultural land area and common water source, and allocated proportional rights to irrigation structures in a way that created a common interest in maintaining irrigation capacity. Relying on a multi-tiered governance structure run by a member-elected leadership, the Zanjera organized water allocation and physical maintenance, and maintained a permanent enforcement and conflict management capacity, with multiple opportunities for appeal to higher administrative levels of the Zanjera. Effective recovery after episodic shocks, including economic downturns and typhoons, was enabled by established rules and procedures and the institutional capacity to activate reserve capacity in different patterned combinations depending on need. Zanjera San Marcelino was resilient in the sense of Holling's ([49], p. 14) original definition of resilience as "a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables". This is resilience as "bouncing back" from a disturbance that threatens the integrity of a well-bounded community by recovering structure and function.

5.3. SES's Adapt to Surprise

Beginning in the 1980s, Zanjera San Marcelino's provision of irrigation services to its membership was threatened by the intervention of an institutional actor that they had no previous experience with, the National Irrigation Administration (NIA). At first leadership from pilot area zanjeras organized an effective resistance to NIA's efforts to integrate farmers into a nationally planned and engineered irrigation system. Zanjera San Marcelino's leadership had similar concerns, and then switched to a cooperative stance after observing that NIA adopted a more collaborative approach in other project areas. A particularly pivotal moment occurred when Zanjera San Marcelino's farmers joined NIA's engineers in field demonstrations of the effectiveness of traditional padilas over proposed double-gated turnouts. Over time the Zanjera and NIA developed closer collaborative relationships and mutual understandings that led to incorporation of NIA's engineered elements into the Zanjera's irrigation system, agreements to take delivery of water from the new dams in exchange for fees and labor commitments, and inclusion of Zanjera San Marcelino in the Madongan River Federated Irrigators' Association. Zanjera San Marcelino's irrigation system became neither wholly traditional and self-governed nor solely engineered and centrally governed, but rather a hybrid of both.

We understand this accommodation and mutual incorporation of NIA and Zanjera San Marcelino's irrigation systems as a resilient response to a potentially disruptive surprise—which is very different than bouncing back from episodic shocks. In this case, faced with an unprecedented situation, the Zanjera resisted changes imposed from outside and then embraced changes that their membership contributed to designing, such as the improved padila described above. Instead of resilience as recovery, this is resilience as adaptive capacity, the ability to cope with surprises while retaining critical functions, structures and feedback mechanisms [9,50].

The concept of adaptive capacity is grounded in a definition of adaptation as "…an adjustment in ecological, social, or economic systems in response to observed or expected changes in environmental stimuli and their effects and impacts in order to alleviate adverse impacts of change" ([51], p. 398). Adaptive capacity is the ability to engage with uncertainty and surprise by exploring multiple possible alternative directions and outcomes, and experimenting with how best to proceed. It is about conscious analysis, planning and design, which could either involve coping and managing to retain a desired state or altering institutional or ecological arrangements to create a preferred system operating space. Crucially, this relies less on the timely application of pre-existing rules or procedures to "bounce back" and more on the exercise of agency and intentionality to identify community desires and preferences. This discovery process requires critical thinking to identify the root causes of conflict and understand underlying power relations that shape constraints and the conditions of possibility in a given moment [52].

It is remarkable that Zanjera San Marcelino can express both of these approaches to resilience, one based on the application of rules to recover from episodic shocks and avoid undesirable thresholds of change, the other on the capacity to generate novel alternatives and mobilize the resources required to adapt to surprise, such as taking over maintenance of the dam and headworks. Organizations that have the capacity to apply rules and standard operating procedures generally are not good at innovation, and are sometimes notoriously sclerotic when facing new and unprecedented challenges to their existence—the classic example being natural resource organizations like the US Forest Service, which for decades continued to focus on fire suppression despite the rising costs and ecological harm from putting every fire out [52]. Codified procedures, rules in practice and channelized behaviors that can enable quick recovery from episodic stress like wildfire may hinder the flexibility to experiment and develop new alternatives [53–55].

Zanjera San Marcelino's ability to respond to shocks and surprises may be grounded in the way it is organized and governed. Many of the same qualities that are described in well-functioning CPRs that bounce back after shocks [1] are also identified by resilience scholars as the basis for creativity and purposeful experimentation after surprises, including:

- A connection to place and dense social networks with ample trust and social capital [56];
- Strong collective choice processes that reflect embedded, shared values [55,57]; and
- High levels of participation and the ability to engage actors in collaborative interaction [58,59].

The same institutional qualities that enabled the Zanjera to persist so long can be associated with its ability to adapt to new circumstances. However, one institutional feature often associated with adaptive capacity that is not characteristic of CPRs is connectivity across scale through polycentric governance. While CPRs are defined as relatively bounded, discrete, and self-sufficient, social-ecological systems are characterized as panarchical [60], with influence flowing both from the bottom-up and top-down across organizational, spatial, and temporal scales. When Zanjera San Marcelino agreed to partner with NIA, its irrigation system become much more explicitly integrated into regional and national social and ecological structures and processes. The Zanjera's willingness to partner provided NIA with an opening to abandon a technocratic engineering model that was failing throughout the country and experiment with including farmers in project design to co-produce an irrigation system that incorporated local knowledge and technology. This illustrates how lower-level actors within a complex adaptive system can impact higher-level organizational actors and potentially realign a broader social-ecological system [60,61]. What was at first an unwanted and unexpected surprise for the Zanjera became, through good timing and canny use of their capacity to influence the situation, a new institutional partner within a multi-scalar and polycentric irrigation system.

5.4. The Power and Vulnerability of Adaptive Capacity

Ironically, this approach proved vulnerable to new challenges that probably would have left the original Zanjera unaffected. Over the next decade the Zanjera-NIA hybrid experienced typhoon damage to NIA infrastructure as the country underwent political regime change. Under the traditional institutional arrangement neither of these disturbances would have had a significant impact on the Zanjera, but under the new hybrid arrangement Zanjera San Marcelino was vulnerable: typhoons, which were a well-anticipated episodic shock to the Zanjera, were a surprise for NIA's new irrigation infrastructure, which was by this time fully integrated into Zanjera-maintained infrastructure. Political regime change led to the loss of patronage for NIA's projects in the region, which left NIA incapable of mounting an effective recovery to typhoon damage.

Zanjera San Marcelino's response was again flexible and adaptive. They organized work crews to repair some of NIA's damaged infrastructure, and reclaimed some of their authority and autonomy to re-initiate traditional irrigation functions. This response was agile and highly context-dependent—in contrast to the rule-governed response of the Zanjera, this was more like the exercise of situational expertise [62], in which people draw on their experience and prior knowledge to rapidly and intuitively interpret a novel situation and take action. It also illustrates how adaptation requires ongoing learning and the ability to continue to adjust by learning from prior mistakes [52]. Zanjera San Marcelino's return to some of its original functions also illustrates how adaptive capacity is an ability to continue to cope with novel situations without foreclosing future options [63].

However, a recent development may pose a more fundamental threat to Zanjera San Marcelino's resilience by degrading the institutional relationships that support adaptive capacity. As noted above, Zanjera members have a declining commitment to fulfilling their work commitments and paying fines, which the Zanjera president attributes in part to changes in inheritance law. This legal change is thus a surprise in the sense discussed above, although to group this legal reform in the same category as a typhoon is a bit ironic, since changing the inheritance law was intended to increase social well-bring by reducing economic discrimination against women and children other than the first born [48].

Nonetheless, this well-meaning law may be even more destructive to Zanjera San Marcelino's integrity than a typhoon. By undermining the Zanjera's collective solidarity, the new law may degrade Zanjera San Marcelino's potential to maintain the collaborative governance structure that is the wellspring for both recovery from shocks and adaptive capacity to respond to surprises. As land holding size shrinks and the importance of where a farmer is located within the Zanjera with respect to irrigation water grows, the trust and reciprocity that underpins social capital diminishes, as does the willingness of farmers to participate in collaborative governance and abide by collective decision making. In addition, irrigation cooperatives that subdivide their land rights tend to be less agriculturally productive over time [64]. It may turn out that the new inheritance law may succeed in unsettling an arrangement that has long withstood both episodic shock and surprise.

It is important not to draw the conclusion that the inheritance law is necessarily a bad thing, though. While surprises are sometimes harmful, they can also be beneficial, by endangering the continuity and integrity of a undesirable arrangement or marking thresholds for system change that offer reformers an opportunity to advance new social–ecological relationships [20]. Addressing inequities in land distribution and gender equity could potentially contribute to redesigning the irrigation system so that it is more equitable and still allows Zanjera San Marcelino to maintain agricultural productivity and community food self-sufficiency. Perhaps we will have an answer to this question after another thirty years of analysis.

6. Conclusions

Our case study traces the institutional longevity and flexibility of a community-based collective resource management regime. Considered over a thirty-year span, Zanjera San Marcelino was not only able to persist, but was also able to adapt in response to unprecedented intervention from the National Irrigation Administration. NIA at first did not even recognize the existence of zanjeras, and then attempted to force pilot area zanjeras to participate in their irrigation scheme, where finally three zanjeras dropped out of the pilot area. Zanjera San Marcelino also resisted NIA's top-down, engineering approach and yet more quickly and substantively engaged NIA in co-design that hybridized their engineered and centrally-managed system with the Zanjera's collectively constructed and maintained irrigation structures. This collaborative relationship had unexpected costs—Zanjera San Marcelino was exposed to national political regime change and typhoons in ways that required ongoing improvisation and renegotiation of the relationship between NIA and the Zanjera, as well as acceptance of new work obligations by zanjera members. Once the Zanjera adapted to NIA they had to go on adapting, as predictability and stability became more and more fleeting, with even old shocks like typhoons becoming new and unprecedented surprises.

Zanjera San Marcelino's shift from recovery to adaptation over this thirty-year analysis paralleled a paradigm shift within natural resource governance research. When the case was initiated in the early 1980s the field focused on how self-governing and relatively contained community organizations allocated resources and responsibilities and responded to episodic shocks [5,65]. The shift occurred as researchers recognized how responding to the challenges of dynamism and scale was essential to addressing natural resource issues in a multi-level, globalized world [66,67]. While the Zanjera was adapting to NIA's intervention, the research field was turning to exploring ways that local organizations were inter-linked within complex governance structures at multiple temporal and spatial scales [1,2,8]. Our study of Zanjera San Marcelino does not just underscore the often stated need to shift focus from the community to the system [2]. Instead, considered over the entire three decades, the case underscores how important community-based management remains within an SES framework. As the scale and dynamism asserted their influence, Zanjera San Marcelino engaged decisively to co-create the NIA-Zanjera hybrid, and then even reasserted its autonomy when budget cuts reduced NIA's ability to recover from typhoons.

Zanjera San Marcelino's community-based governance approach not only enabled it to respond to shocks with persistence, it also was highly adaptive to surprise. Other researchers have observed how communities that have high internal and low external connectivity can recover quickly [68], while those with a higher degree of external connectivity have an increased capacity for adaptation [57,69,70]. The same kind of observation about the tension between recovery and adaptation has been made in reference to the susceptibility of highly structured natural resource management organizations to "rigidity traps" [50,58]. This case illustrates liminality across this divide, as a community accepts higher connectivity on their own terms, and then scales these connections back when they are no longer advantageous. Seen over a long time frame, Zanjera San Marcelino was effective in both maintaining its rules and procedures as well as adapting by changing these agreements and collective-action structures when circumstances shifted. These capacities are not only correlated, as Wilson *et al.* [57] found in a study of two rural communities in Australia, they may also be causatively linked: by having CPR structures in place that maintained a system of mutually agreed upon rules and procedures, the Zanjera may also gain the potential to reflect, reconsider, negotiate, and reconfigure when circumstances shifted. This speaks for the continued utility of community-based case studies, embedded within a broader institutional milieu and within a highly variable and unpredictable social and ecological context. As we shift the paradigm from a CPR to an SES perspective we should not just discard the prior paradigm, but rather embed an appreciation for the distinctive qualities of community based resource management within a broader scope.

Along with this appreciation for how governance within Zanjera San Marcelino can support resilience, the case highlights how the institutional conditions that sustain a CPR [5] may be vulnerable to disruption within an SES, and that this vulnerability may be reducing the Zanjera's ability to maintain adaptive capacity. The Zanjera held up well after integration with NIA despite no longer strictly operating under some of these diagnostic CPR conditions, such as well-defined boundaries and locally devised access and management rules. However, one of the surprises that occurred—a well-intentioned change in inheritance laws—had worrisome implications for Zanjera San Marcelino because, as time passes, it can slowly and subtly reduce many irrigators' sense that they share a common interest in contributing labor and resources to sustain the overall operation of the Zanjera. This is the foundation for collective action within the Zanjera, and diminishing it could act in the same way as an immune system disorder reduces an organism's capacity to respond to other diseases.

Neither centralized nor decentralized institutional approaches are effective in coping with cross-scalar influences like these [71]. Rather, there is evidence that polycentric approaches can enhance the effectiveness of community-based governance within an SES, engaging communities and government agencies in ways that build on their respective strengths [72,73]. In 2010, Zanjera San Marcelino joined the Ilocos Service Associations Group, a network of zanjeras that engages in information sharing to support collaborative learning. Networks such as this are well-suited to enhance the adaptive capacity of community-based groups by devising a diversity of responses to rapid change and uncertainty [59]. Learning networks are informal associations whose aims are to enhance the autonomy and integrity of governance at the community-scale while mediating relationships to other scales [69,74]. They achieve this by nurturing and distributing knowledge between communities in ways that are low cost and contextually relevant, supporting collective learning while coordinating enough to amplify the potential to navigate regime shifts and catalyze fundamental change in policy and institutions at higher scales [59,64]. At their best, learning networks can expand the diversity of options, ideas, and practices that support system innovation by coordinating experiments that are defined and conducted by those closest to the problem [52,72,74,75]. Joining in the Ilocos Service Associations Group could potentially have far-reaching impacts as Zanjera San Marcelino continues to experiment with new ideas, relationships, and agreements and translate them into more enduring forms.

Acknowledgments

We wish to thank the editors and anonymous reviewers for their comments and suggestions. We are grateful to Zanjera San Marcelino's members and leaders for their extensive time in interviews, meetings, and field visits. Thank you to E. Walter Coward who introduced Yabes to the zanjeras and INIP (1985–2010). We appreciate NIA staff's information about NIA, INIP, and the Zanjera. We value the 25 years of research work and support of Sosima Rocimo Demandante and Jocelyn Aoalin, and by four other research assistants. Funding support in 1985–1986 was provided by a NSF Doctoral Studies grant and through the Fulbright-Hayes program.

Author Contributions

Yabes has been conducting fieldwork with the Zanjera San Marcelino since 1985. From 2012–2015, Yabes and Goldstein drew together select elements of Yabes fieldwork to focus on how Zanjera San Marcelino persisted through episodic shocks and adapted to surprises. The two authors regularly exchanged drafts and ideas, with Yabes selecting and structuring the case data and Goldstein developing a unifying theoretical framework grounded in the resilience literature, interpreting the case data within that framework, and drawing conclusions from this analysis.

Conflicts of Interest

The authors declare no conflict of interest.

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